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A HANDHELD CALCULATOR (HHC) PROGRAM FOR THERMAL IMAGING TARGET --ETC(U)
JAN 82 J R MOULTON, G H KORNFELD

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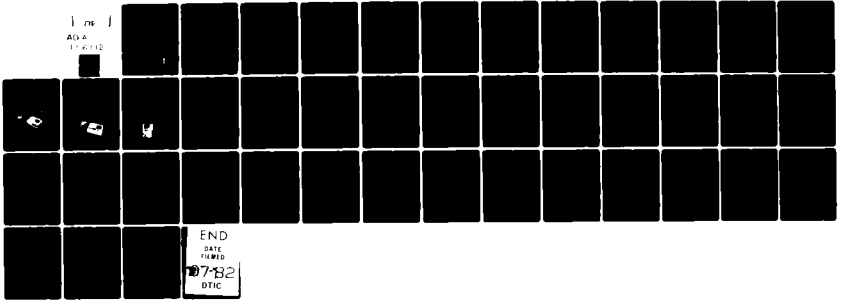

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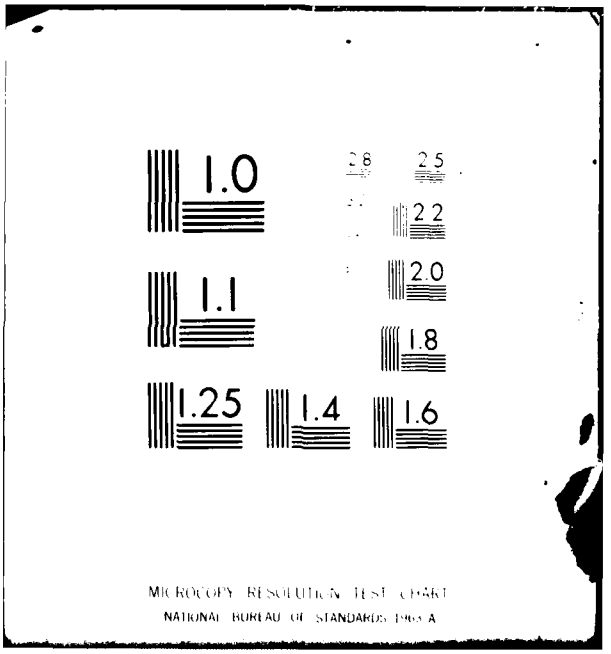
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Report DELNV-TR-0030

A HANDHELD CALCULATOR (HHC) PROGRAM FOR THERMAL IMAGING TARGET ACQUISITION ANALYSIS – A USER'S GUIDE

by
Joseph R. Moulton
and
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January 1982

U.S. ARMY ELECTRONICS R&D COMMAND
NIGHT VISION & ELECTRO-OPTICS LABORATORIES
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The proliferation of thermal imaging sensors to most major weapon platforms has broadened the need for FLIR performance analysis capability throughout the Army. To date, the Army analysis capability has been concentrated within the Visionics Division of the Night Vision and Electro-Optics Laboratory except for the target acquisition codes that have been incorporated within the Army Wargames. This report describes one of several activities of NV&EOL to disseminate analysis capability to a broad spectrum of

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Army elements so that each may undertake independently routine FLIR performance calculations as required. Although these analytical models are incorporated entirely within a handheld calculator (HHC) and designed for simplicity in their use, they provide a comprehensive performance analysis capability. This capability stems from unique analytical fits to higher level models and from the remarkable capacity of the new HP 41CV programmable handheld calculator. This report provides a complete user's guide in the application of HHC programs to FLIR analysis problems for requirements frequently encountered by FLIR and weapon platform designers, applications analysis, tacticians, and battlefield commanders. A companion report that provides a technical description of this work is in progress. Operation of the HHC requires minimal instruction and all actions of the operator are prompted by displayed alphanumeric inquiries. Target acquisition analysis under adverse weather are routinely computed using this HHC model, providing ranges for detection, classification, recognition and identification for a variety of US and Warsaw Pack Armor vehicles. The model enables the user to quickly determine search times for a given search sector as well as target acquisition probabilities for weather and signature conditions specified. Atmospheric transmission in the 8-12 μm and visual spectral region can be routinely determined for any specified range based on an abbreviated form of LOWTRAN V, EO SEAL and G/AP atmospheric models.

SUMMARY

The proliferation of thermal imaging sensors to most major weapon platforms has broadened the need for FLIR performance analysis capability throughout the Army. To date, the Army analysis capability has been concentrated within the Visionics Division of the Night Vision and Electro-Optics Laboratory except for the target acquisition codes that have been incorporated within the Army Wargames. This report describes one of several activities of NV&EOL to disseminate analysis capability to a broad spectrum of Army elements so that each may undertake independently routine FLIR performance calculations as required. Although these analytical models are incorporated entirely within a handheld calculator (HHC) and designed for simplicity in their use, they provide a comprehensive performance analysis capability. This capability stems from unique analytical fits to higher level models and from the remarkable capacity of the new HP 41CV programmable handheld calculator.

This report provides a complete user's guide in the application of HHC programs to FLIR analysis problems for requirements frequently encountered by FLIR and weapon platform designers, applications analysis, tacticians, and battlefield commanders. Operation of the HHC requires minimal instruction and all actions of the operator are prompted by displayed alphanumeric inquiries. Target acquisition analysis under adverse weather are routinely computed using this HHC model, providing ranges for detection, classification, recognition and identification for a variety of US and Warsaw Pact Armor vehicles. The model enables the user to quickly determine search times for a given search sector as well as target acquisition probabilities for weather and signature conditions specified. Atmospheric transmission in the 8-12 μm and visual spectral region can be routinely determined for any specified range based on an abbreviated form of LOWTRAN V, EO SAEL and G/AP atmospheric models.

A companion report[1] now in progress provides a technical description of the HHC algorithms used as well as the technical genesis of the analytical forms. In general, the performance model is based on the Johnson Criteria,[2] as applied to analytical equations similar to those described by Ratches et al.[3] for static range performance, and by Lawson,

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[1] G. Kornfeld and J. R. Moulton, *Technical Description of HHC Target Acquisition Program (TGT ACQ)* (In Progress).

[2] J. Johnson, *Analysis of Image Forming Systems*, Proceedings of the Image Intensifier Symposium (1958).

[3] J. A. Ratches, W. R. Lawson, L. P. Obert, R. J. Bergmann, T. W. Cassidy, and J. M. Swenson, *Night Vision Laboratory Static Performance Model for Thermal Viewing Systems*, USA Electronics Command Report ECOM-7043 (April 1975).

Cassidy and Ratches[4] for search time performance. The basis for the atmospheric analysis stems from analytical fits to LOWTRAN V.[5] by Kornfeld[6] and the NVL G/AP Aerosol Data Base[7] by Shields.[8] All atmospheric algorithms used in the HHC program are believed to be similar to those in the current version of EO SAEL.[9] The thermal imagers listed in this user's guide as sensors 1 *through* 4 are identified in the Visionics Performance Handbook[10] by Obert et al.

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[4] W. R. Lawson, T. W. Cassidy and J. A. Ratches, *A Search Model*, IRIS Specialty Group on Imaging, Naval Academy, Annapolis, MD, June 78 (Confidential).

[5] F. X. Kneizys, *Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 5*, AFGL-TR-80-0067, February 1980.

[6] G. Kornfeld, *A LOWTRAN Equivalent Computer Program*, NV&EOL internal report, February 1981.

[7] J. R. Moulton, R. J. Bergemann, and M. C. Sola, *(S) European Winter Atmospheric Environment (U)*, IRIS Proceedings (August 1976).

[8] F. J. Shields, Internal NV&EOL DF, subject: *NV&EOL G/AP Aerosol Atmospheric Models* (7 September 1978).

[9] Louis D. Duncan, editor, *EOSAEL 80, Vol. I: Technical Documentation*, Atmospheric Sciences Laboratory Report ASL-TR-0072, January 1981.

[10] L. P. Obert, J. T. Wood, C. J. Nash, *(C) Visionics EO Sensor Performance Handbook VOL I (Natural European Environments) (U)*, June 1981.

CONTENTS

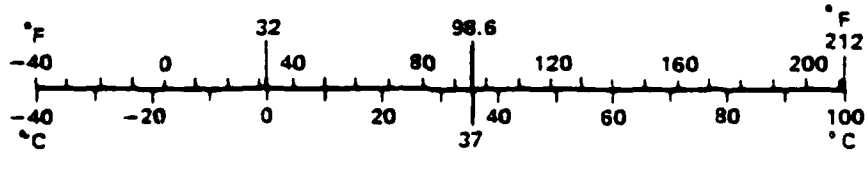
ILLUSTRATIONS

TABLES

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	metric ton	t
		VOLUME		
tsp	teaspoons	5	milliliters	mL
Tbsp	tablespoons	15	milliliters	mL
in^3	cubic inches	16	milliliters	mL
fl oz	fluid ounces	30	milliliters	mL
c	cups	0.24	liters	L
pt	pints	0.47	liters	L
qt	quarts	0.95	liters	L
gal	gallons	3.8	liters	L
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	degrees Fahrenheit	5/9 (after subtracting 32)	degrees Celsius	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10 000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	metric ton (1000 kg)	1.1	short tons	
		VOLUME		
mL	milliliters	0.03	fluid ounces	fl oz
mL	milliliters	0.06	cubic inches	in^3
L	liters	2.1	pints	pt
L	liters	1.06	quarts	qt
L	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	degrees Celsius	9/5 (then add 32)	degrees Fahrenheit	°F

A HANDHELD CALCULATOR (HHC) PROGRAM FOR THERMAL IMAGING TARGET ACQUISITION ANALYSIS — A USER'S GUIDE

I. INTRODUCTION

Thermal Imaging Sensors, often referred to as FLIRs are incorporated into most major Army weapon platforms to provide target acquisition capability under day/night, semi-adverse weather and obscured battlefield conditions. The acquisition capability provided by thermal imagers is dependent upon many factors: i.e., sensor parameters, target range, target type, target history, weather type, intensity and duration, operator training, terrain structure, tactical employment, etc. The calculations of this target acquisition capability has been, heretofore, performed by analysts highly trained in thermal imaging, environmental and computer technologies. The objective of this effort is to provide the typical user of thermal imager analysis, whether he be a weapons developer, TRADOC tactician or FLIR developer, the capability of carrying out performance analysis independently at his desk after a few minutes tutorial. The analysis equipment (HHC) is a Hewlett Packard 41CV Handheld Calculator with or without a HP 82143A printer that has been programmed with unique performance algorithms developed at the Night Vision and Electro-Optics Laboratory. These performance algorithms are for the most part condensed versions of large scale computer programs currently used with a computer main frame. Although the HHC program is currently limited to thermal imaging sensors, future versions will address target acquisition analysis of day optics and television sensors as well.

Although the HHC equipment and algorithms are unclassified, programs are of such design that when used in conjunction with classified sensor parameters, classified target acquisition anlaysis can be performed as well. Discretion is required, however, on the part of the user to insure that analysis results are properly protected whenever classified sensors are considered.

In addition to this Introduction section, this report contains sections that describe the design and application of this analysis tool for a variety of target acquisition problems. Taken in their entirety, these sections serve as a user's guide for conducting thermal imaging anlaysis using the HHC target acquisition model. Specifically, Section II gives a description of the HP 41CV hardware and an overview description of the program. As described, the programs are executed interactively with the HHC operator using the full alphanumeric capability of the HP 41CV. Responses to the HHC's inquiries not readily known by the operator are listed in this section. A more detailed description of the HHC

hardware is provided by the manufacturer.[1] In addition, a full technical description of the algorithms is provided.[1] Section III gives illustrative examples of using the HHC to obtain the target acquisition capability for a typical thermal imager as well as performance variations one could expect for a variety of weather conditions. The examples used enable one to calculate the range dependent target acquisition capability of detection, classification, recognition and identification for the thermal sights under the weather conditions considered. Further, the examples illustate the probability of accomplishing this range dependent target acquisition and the search time requied for a given search field of view. In addition, examples are given that enables one to calculate atmospheric propagation in the 8- to 12-μm spectral band for different weather conditions and ranges. The atmospheric propagation calculations allow the user to better understand the atmospheric influence on target acquisition performance.

The HHC hardware is shown in Figure 1, illustrating the HP 41CV Handheld Calculator with the magnetic card reader HP 82104A and alphanumeric printer HP 82143A. A plug-in module (not shown) called a STAT PAC can be used for input data preparations.

Figure 1. HP 41CV HHC hardware used for thermal imager performance analysis.

[1] Hewlett Packard, *The HP-41C/41CV Alphanumeric Full Performance Programmable Calculator, Owner's Handbook and Programming Guide*, September 1980.

The HP 41CV is a commercially available handheld calculator that provides considerable computational capability to the user even without the Target Acquisition Model. This capability is fully described in the HP 41CV Owner's Handbook and Programming Guide that is provided with the calculator, hence will not be repeated in this report. As shown in Figure 1, the printer is connected to the calculator via a single cable, whereas the magnetic card reader is attached to the calculator as a plug-in attachment. The Target Acquisition Model is written on magnetic cards that are read into the HHC using the card reader. The HP 41CV has continuous memory that preserves the program even after the HHC has been turned off; hence, once read, most users will rarely require additional card reading. Card reading will only be required when the Target Acquisition Model has been cleared from the HHC.

The printer and the HHC each contain rechargeable battery packs; hence, operation in remote field sites without d.c. power is no problem. A battery charging element is provided for the calculator and the printer that enables operation from US standard d.c. current as well.

A closeup of the HP 41CV HHC keyboard is shown in Figure 2. Once the program is loaded in the HHC, the operator uses only the On, User, A, number key 0 to 9, and the Run Key identified as R/S. As will be described in the following paragraphs, the response requirements by the user are generally limited to numerical keys 0 to 9, decimal dot, and R/S keys once the On, User, and letter keys have been executed.

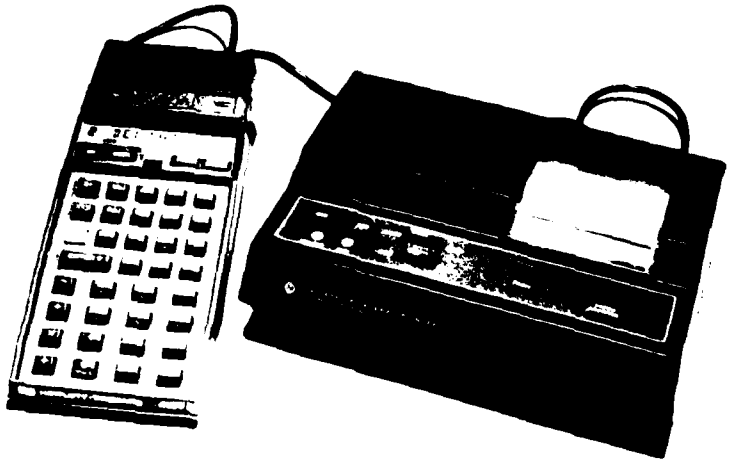


Figure 2. Closeup of HHC hardware keyboard.

The user of the HHC for target acquisition analysis should first acquaint himself with the basic keyboard functions and display modes. The keyboard has 3 color schemes as follows:

White Key Lettering —	Normal functions activated by key slelection.
Gold Key Lettering —	2nd level function activated by first striking gold key (shift), then hitting desired key.
Blue Key Lettering —	Alphanumeric functions activated by first striking ALPHA key, then hitting desired key. For numbers and small letters, strike gold shift key when in ALPHA mode.
White Mode Key (Top) — (Figure 3)	On turns calculator on. On again turns calculator off.
	User selects user mode. User again removes user mode.
	PRGM selects program mode. *Do not select PRGM mode except for card* writing; otherwise, modification of TGT__ACQ Program may result. PRGM again removes PRGM. (Note: __ represents a space.)
	ALPHA selects alphanumeric mode. ALPHA again removes ALPHA.

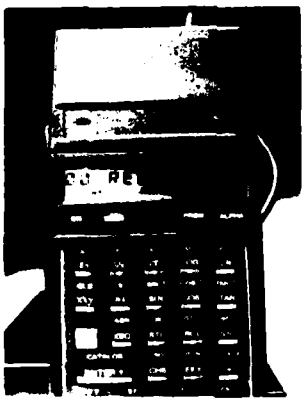


Figure 3. Mode keys with display (insufficient registers).

The STAT PAC is a small application module that inserts into the top of the 41CV calculator that allows curve *fitting of FLIR MRT data required* as an input to the TGT__ACQ Program.

The Peripheral Printer keyboard is self-explanatory. Normal mode of usages is On, Dark, and Normal switch positions. Paper is advanced by striking Paper Advance Key. The Print Key prints whatever is displayed on the HHC display. *Caution is required* when in the PRGM mode since these keys insert print or advance instruction in the TGT__ACQ Program.

II. OVERVIEW OF HHC TARGET ACQUISITION MODEL

The target acquisition algorithms described in this section have been developed for use in conjunction with the Hewlett Packard 41CV Handheld Calculator for the purpose of enabling the user to carry out thermal imager performance analysis independently at his desk or remote field site with as little as minutes of instruction. Target acquisition analysis capability provided include range, probability, and search time for the mission tasks of detection, classification, recognition, and identification. The algorithms are pro*grammed into the* 41CV *in a manner* to simplify user-response by taking full advantage of the alphanumeric capability of the HP 41CV. For the most part, the user need only answer the displayed inquiry of the HHC which he does by pressing numerical keys, then the R/S key. Because of these continuing displayed interrogatives, the user concentrates his attention on the analysis task instead of the mechanics of operating the HHC. In other words, the HHC keeps track of the mechanics of analysis so that the user can concentrate on understanding the analysis.

There are three elements associated with the HHC Performance Models, which are:

- HP 41CV Calculator and Peripherals (hardware).
- Target Acquisition and Atmospheric Program (software on magnetic cards).
- User's Guide (this report).

The User's Guide is this report, hence needs no further explanation. The other two elements will be described as follows:

HP 41CV CALCULATOR AND PERIPHERALS

The HP 41CV hardware consists of the following:

- HP 41CV Handheld Calculator.
- HP 82143A Peripheral Printer.
- HP 82104A Card Reader.
- HP 00041 — 14001 (15002) STAT PAC.
- HP 00097 — 13143 120 Blank Cards.

The HHC Target Acquisition Program is coded on 7 magnetic cards under the title of TGT__ACQ.

PROGRAM TGT__ACQ LOADING

As mentioned previously, the Target Acquisition Program entitled TGT__ACQ is written on 7 magnetic cards. These cards are read into the HHC as follows:

- Allocate 30 data registers XEQ ALPHA SIZE ALPHA 030.
- Check for availability of at least 207 program registers PRGM GTO . . Displayed number is available registers.

If insufficient program registers are available, clear existing programs as follows:

Catalog 1 displays existing program names XEQ ALPHA CLP ALPHA, ALPHA (Key in program name) ALPHA.

- *Without* being in the PRGM Mode, insert each card twice into the card reader, once in each direction. The display indicates RDY nn of 13 each time with nn being the lowest numbered card yet to be read. Repeat card side if error message is displayed. Upon completion of last card, working is displayed.
- Test execution of TGT__ACQ by:

User Mode, Σ— (i.e., strike "Shift" Key then "A" Key; Printer? is displayed if program is properly loaded.).

EXECUTING TGT__ACQ PROGRAM

The following description assumes the seven magnetic cards containing the Target Acquisition Analysis Program TGT__ACQ has been read into the HHC and turned on. Further the HHC has been put in the "User" mode, and "PRGM" or "ALPHA" mode was not selected. Upon striking the "Shift" and "A" Key, the HHC takes command and prompts the user as to each subsequent action through interactive inquiries. The user responds to the inquiries by key striking an appropriate numerical value then executes by striking the Run/Stop Key identified as "R/S." For example, after striking "Shift" and "A," the inquiry "Printer?" is displayed. The user responds by striking the 1 Key and the R/S Key if the printer is hooked to the HP 41CV. If not, the user strikes Ø, R/S. Hence 1 = yes and Ø = no and R/S implements.

The specific inquiries presented to the HHC user are described in Table 1.

The matrix codes allow the user to obtain the target acquisition performance for each of the five discrimination tasks (Easy Detection, Cluttered Detection, Classification Recognition, and Identification) by entering either "20," "30," or "40," then "R/S." If only one target acquisition performance is desired, say Recognition Probability, the user selects the appropriate matrix code, i.e., 34 for Recognition Probability. After the target acquisition performances are displayed, the HHC returns to the "change?" inquiry. The matrix code used in conjunction with the change inquiry allows the user to rapidly parameterize target acquisition performance as a function of the battlefield environment.

There is one additional response to the Analysis No.? inquiry, being 97.

97	Upon keying in 97 or TR in Blue Keys, meaning transmission, the HHC asks the range for which the transmission is to be
Range?	calculated. User responds with range in km, then R/S.

Table 1. TGT_ACQ Program Responses

No. HHC Display	User Response Options
Printer?	1 = Yes, 0 = No
1 Sensor?	1 = NFOV[12] 2 = WFOV[12] 3 = NFOV[12] 4 = WFOV[12] 5 = New FLIR (See MRT Data preparations using STAT PAC instructions later in this section)
HORZ FOV?	Key in value for New FLIR in degrees
a value?	Key in a value of MRT curve fit
b value?	Key in b value of MRT curve fit
2 DELTA T?	Key in value of target Δ T in °C
3 Target No.?	1 = M113 2 = M60A1, 3 = M60A1 Hulldown 4 = M109, 5 = M109 Hulldown 6 = M551, 7 = M551 Hulldown 8 = DIVAD, 9 = DIVAD Hulldown 10 = T-62, 11 = T-62 Hulldown 12 = T-72, 13 = T-72 Hulldown 14 = T-64, 15 = T-64 Hulldown 16 = ZSU, 17 = ZSU Hulldown
4 ACQ PROB?	Value of probability of acquisition desired (0.0 to 1.0)
5 Weather?	1 = Clear, Hazy or Foggy 2 = Rain with Haze or Fog
6 Visual RG?	Value of visual range desired in km (0.0 to 50.0 km)
7 Rel Humid?	Value of Relative Humidity desired (0.0 to 1.0)
8 Air Temp?	Value of air temperature desired in degrees Celsius (°C)
Rain Rate?	Rain rate desired in mm/h (1.0 to 50 mm/w)

[12] L. P. Obert, J.T. Wood, C. J. Nash, *(C) Visionics E-O Sensor Performance Handbook VOL I (Natural European Environments)*, Pages 5-2/4 and 5-6 (U), June 1981.

Table 1. TGT_ACQ Program Responses (Cont'd)

No. HHC Display	User Response Options
Changes?	One number 1 to 8 if any of the above responses need changed. If no changes are necessary, press R/S.
Analysis No.?	There are a variety of target acquisition analysis possible that can be selected by number. The specific analysis is requested using the matrix code in Table 2.
Search FOV? Range? What PROB?	Upon selection of the Matrix Code 40-45, the inquiries are generated for the user to answer in sequence. For the search FOV, the user enters the horizontal search field in degrees,then depresses "R/S." The range inquiry is answered by keying in the target range in km. The target acquisition probability for unlimited time (MAX PROB) is then displayed followed by what PROB? The user then selects a detection probability less than the value of MAX PROB shown in decimal fraction. Upon depressing the "R/S" Key, the HHC then gives the time to accomplish the target acquisition function for the search FOV and level of certainty (probability) requested.
Range?	User selection of Matrix Codes 30 to 35 generates this inquiry. The user enters the range in km (nearest tenth) to the target for which the probability is to be determined, and depresses "R/S."

Table 2. TGT_ACQ Analysis Number Responses

Matrix Codes	21	22	23	24	25
20	Easy Detection Range	Cluttered Detection Range	Classification Range	Recognition Range	Identification Range
	31	32	33	34	35
30	Easy Detection Probability	Cluttered Detection Probability	Classification Probability	Recognition Probability	Identification Probability
	41	42	43	44	45
40	Time to Easy Detection	Time to Clutter Detection	Time to Classify	Time to Recognize	Time to Identify

ANALYSIS OF NEW FLIRS

If the user selected 5 as his response to the 1 Sensor? inquiry, he needs to determine the a and b values that are requested by the HHC. These a and b values are found from the new FLIR MRT data using the HHC with the STAT PAC inserted by keying the HHC as follows:

XEQ ALPHA CL Σ E X P ALPHA

A chime sounds when the HHC is ready for the MRT data. The MRT is entered in pairs of value. The first value is the spatial frequency which is keyed in and followed by striking the Enter Key. The second value keyed in is the Δ T for that spatial frequency followed by striking the "A" Key. Continue this process with the next MRT data point of spatial frequency and MRT value, and the next, etc., until all MRT data is entered. When completed, press "E" and the HHC prints out the a and b values. In addition to the a and b value, the correlation coefficient of Fit, R^2, is provided the user. Also, the HHC provides the MRT value for any spatial frequency when the user keys in the spatial frequency an F follows with striking the R/S Key. The MRT value displayed is for the curve fitted MRT data.

The above a and b values are used to respond to the inquiries when the user has selected a new FLIR: i.e., answered the question Sensor? (Step 1) with 5.

III. ILLUSTRATIVE APPLICATIONS OF HHC ANALYSIS

The HHC Program named TGT__ACQ is listed in the Appendix in its entirety. Several examples of the application of TGT__ACQ to target acquisition analysis are provided in this section. The examples are:

Case I — FLIR Range Performance (Table 3).

Case II — Search Time and Recognition Probability (Table 4).

Case III — Performance vs MRTs and Transmission (Table 5).

Case I. FLIR Range Performance.

The range performance for Sensor 1 as a function of visual range was calculated and the results summarized in Table 3. A copy of the display was printed and is provided in Table 6. The summary table shows the degrading part of FLIR target acquisition performance as the visibility diminishes. Note this example used the Matrix Code 20 to obtain the value of each of the five target acquisition tasks.

Case II. Search Time and Recognition Probability.

This example continues with the same sensor and weather conditions used in Case I, but illustrates the use of Matrix Codes 34 and 41. Had one used the Matrix Code 30 and 40, the search time and recognition probability would have been obtained for all 5 target acquisition tasks as in Case I. The ability to select the specific target acquisition task of interest saves considerable time when one is weather parameterizing various target acquisition task performances. The summary of the results of Case II is given in Table 4 and the display printout is listed in Table 6. The search time remains at a constant value for the visibilities of 7, 3, and 1 km since the detection probability is 1 for those conditions. The probability drops from 1 for the low visibility of 0.5 km, thus increasing the search time at that point.

Case III. Recognition Performance Versus MRTs and Transmission.

As shown in Tables 7 and 8, this case illustrates the HHC Programs ability to analyze different MRTs using data available to the user. The MRT data is keyed into, as described in Section II using the STAT PAC for new FLIR analysis. In addition, this case selected Analysis No. 97; i.e., the mode that produces the 8- to 12-μm transmission for any range requested. Table 5 provides a summary of the data obtained for the weather conditions given.

The above three cases serve to illustrate the breath of analysis possible using the HHC TGT__ACQ Program. Many other and more detailed target acquisition analyses are possible. If in the process of such analysis any program errors are discovered, the user is requested to contact the Systems Analysis Team, Visionics Division of the Night Vision and Electro-Optics Laboratory at (703) 664-5843 or Autovon 354-5843.

Table 3. Predicted Range Performance

Visual Range (km)	Easy Det	Clut Det	Class	Rec	ID
7.0	20.96	8.96	5.10	2.74	1.43
3.0	18.45	8.47	4.94	2.69	1.41
1.0	6.89	4.80	3.41	2.17	1.25
0.5	2.06	1.82	1.58	1.25	0.88

Conditions

Sensor = 1.0
Delta T = 5.0
Target # = 12.0
ACQ PROB = 0.5
Weather = 1.0
Rel Humid = 0.90
Air Temp = 10.0
Visual Range = as indicated

Table 4. Predicted Search Time and Recognition Probability

Visual Range (km)	2 km REC PROB.	2 km Search Time (s)
7.0	0.78	30.74
3.0	0.77	30.74
1.0	0.59	30.74
0.5	0.002	40.94

Conditions

Sensor = 1.0
Delta T = 5.0
Target # = 12.0
ACQ PROB = 0.5
Weather = 1.0
Rel Humid = 0.90
Air Temp = 10.0
Visual Range = as indicated

Search FOV = 30 deg
Range = 2.0 km

Table 5. Predicted Recognition Performance Versus MRTs and Transmission

Visual Range (km)	MRT #1 REC (W/O Rain)	MRT #2 REC (W/O Rain)	MRT #2 REC (W/Rain)	0.5 km Transmission 8-12 km	0.5 km Transmission Visual
7.0	3.74	2.74	1.88	.59	.50
3.0	3.65	2.69	1.80	.56	.34
1.0	2.74	2.17	1.14	.25	.09
0.5	1.42	1.25	0.60	.03	.01

Conditions

Sensor = 1 and 5
Delta T = 5.0
Target # = 12.0
ACQ PROB = 0.5
Rain Rate = 5 mm/h
Weather = 1.0
Rel Humid = 0.90
Air Temp = 10.0
Visual Range = as indicated

Table 6. Display Listing for Range Performance Example

```
          AEQ TGT ACQ
PRINTER?
            1.00    RUN
1 SENSOR?
            1.00    RUN
2 DELTA T?
            5.00    RUN
3 TARGET NO.?
           12.00    RUN
4 ACQ PROB?
             .50    RUN
5 WEATHER?
            1.00    RUN
6 VISUAL RG?
             .50    RUN
7 REL HUMID?
             .50    RUN
8 AIR TEMP?
           10.00    RUN
======
CHANGES?
                    RUN
ANALYSIS NO?
           20.00    RUN
DETECTED
RANGE 3.06
CLUT DETECT
RANGE 1.52
CLASSIFIED
RANGE 1.2
RECOGNIZED
RANGE 1.05
IDENTIFIED
RANGE 0.69
======
CHANGES?
            6.00    RUN
6 VISUAL RG?
            1.00    RUN
```

```
======
CHANGES?
                    RUN
ANALYSIS NO?
           20.00    RUN
DETECTED
RANGE 6.09
CLUT DETECT
RANGE 4.06
CLASSIFIED
RANGE 3.41
RECOGNIZED
RANGE 2.17
IDENTIFIED
RANGE 1.25
======
CHANGES?
            6.00    RUN
6 VISUAL RG?
            3.00    RUN
======
CHANGES?
                    RUN
ANALYSIS NO?
           20.00    RUN
DETECTED
RANGE 16.45
CLUT DETECT
RANGE 6.47
CLASSIFIED
RANGE 4.94
RECOGNIZED
RANGE 2.69
IDENTIFIED
RANGE 1.41
======
CHANGES?
            6.00    RUN
6 VISUAL RG?
            7.00    RUN
```

```
======
CHANGES?
                    RUN
ANALYSIS NO?
           20.00    RUN
DETECTED
RANGE 20.96
CLUT DETECT
RANGE 8.96
CLASSIFIED
RANGE 5.10
RECOGNIZED
RANGE 2.74
IDENTIFIED
RANGE 1.43
======
CHANGES?
                    RUN
ANALYSIS NO?
           34.00    RUN
RANGE?
            2.00    RUN
RECOGNIZED
PROBABILITY 0.78
======
CHANGES?
                    RUN
ANALYSIS NO?
           41.00    RUN
SEARCH FOV?
           30.00    RUN
RANGE?
            2.00    RUN
DETECTED
MAX PROB 1.00
WHAT PROB?
             .50    RUN
TIME 30.74

=
CHANGES?
```

```
======
CHANGES?
                    RUN
ANALYSIS NO?
           34.00    RUN
RANGE?
            2.00    RUN
RECOGNIZED
PROBABILITY 0.77
======
CHANGES?
                    RUN
ANALYSIS NO?
           41.00    RUN
SEARCH FOV?
           30.00    RUN
RANGE?
            2.00    RUN
DETECTED
MAX PROB 1.00
WHAT PROB?
             .50    RUN
TIME 30.74

======
CHANGES?
            6.00    RUN
6 VISUAL RG?
            1.00    RUN
======
CHANGES?
                    RUN
ANALYSIS NO?
           34.00    RUN
RANGE?
            2.00    RUN
RECOGNIZED
PROBABILITY 0.53
======
CHANGES?
```

```
ANALYSIS NO?
           41.00    RUN
SEARCH FOV?
           30.00    RUN
RANGE?
            2.00    RUN
DETECTED
MAX PROB 1.00
WHAT PROB?
             0.50   RUN
TIME 30.74

======
CHANGES?
            6.00    RUN
6 VISUAL RG?
             .50    RUN
======
CHANGES?
                    RUN
ANALYSIS NO?
           34.00    RUN
RANGE?
            2.00    RUN
RECOGNIZED
PROBABILITY 0.53
======
CHANGES?
                    RUN
ANALYSIS NO?
           41.00    RUN
SEARCH FOV?
           30.00    RUN
RANGE?
            2.00    RUN
DETECTED
MAX PROB 1.00
WHAT PROB?
             .50    RUN
TIME 30.74
```

Table 7. Display Listing for Different MRT Example

```
                XRUN "ZERO"
ZERO
                0.95 ENTER?
                .876  ZERO A
                2.18 ENTER?
                0.17  ZERO A
                3.09 ENTER?
                5.26  ZERO A
                3.98 ENTER?
                0.46  ZERO A
                4.91 ENTER?
                1.06  ZERO A
                5.44 ENTER?
                1.38  ZERO A
                      ZERO E
A=0.95
B=0.83
C=0.63
                1.00    RUN
Y.=0.85
              XERO "TGT AQG
PRINTER?
                1.00    RUN
1 SENSOR?
                5.00    RUN
HORZ FOV?
                2.30    RUN
3 VALUE?
                 .83    RUN
6 VALUE?
                 .63    RUN
2 DELTA T?
                5.00    RUN
3 TARGET NO.?
               12.00    RUN
4 AIR PRES?
                 .98    RUN
5 WEATHER?
                1.00    RUN
6 VISUAL RQ?
                7.00    RUN
7 REL HUMID?
                 .98    RUN
8 AIR TEMP?
               10.00    RUN
```

```
******
CHANGES?
                        RUN
ANALYSIS NO?
               24.00    RUN
RECOGNIZED
RANGE 3.74
******
CHANGES?
                6.00    RUN
6 VISUAL RQ?
                3.00    RUN
******
CHANGES?
                        RUN
ANALYSIS NO?
               24.00    RUN
RECOGNIZED
RANGE 3.65
******
CHANGES?
                6.00    RUN
6 VISUAL RQ?
                1.00    RUN
******
CHANGES?
                        RUN
ANALYSIS NO?
               24.00    RUN
RECOGNIZED
RANGE 3.17
******
CHANGES?
                6.00    RUN
6 VISUAL RQ?
                 .50    RUN
******
CHANGES?
                        RUN
ANALYSIS NO?
               24.00    RUN
RECOGNIZED
RANGE 1.42
```

```
******
CHANGES?
                2.00    RUN
1 SENSOR?
                1.00    RUN
******
CHANGES?
                        RUN
ANALYSIS NO?
               24.00    RUN
RECOGNIZED
RANGE 1.25
******
CHANGES?
                6.00    RUN
6 VISUAL RQ?
                1.00    RUN
******
CHANGES?
                        RUN
ANALYSIS NO?
               24.00    RUN
RECOGNIZED
RANGE 1.17
******
CHANGES?
                6.00    RUN
6 VISUAL RQ?
                3.00    RUN
******
CHANGES?
                        RUN
ANALYSIS NO?
               24.00    RUN
RECOGNIZED
RANGE 1.00
******
CHANGES?
                6.00    RUN
6 VISUAL RQ?
                2.00    RUN
```

```
******
CHANGES?
                        RUN
ANALYSIS NO?
               24.00    RUN
RECOGNIZED
RANGE 1.74
******
CHANGES?
```

Table 8. Display Listing for Atmospheric Data Example

```
          XEQ  TAT ACQ?
PRINTER?
              1.00    RUN
1 SENSOR?
              1.00    RUN
2 DELTA T?
              5.00    RUN
3 TARGET NO.?
             12.00    RUN
4 ACQ PROB?
               .50    RUN
5 WEATHER?
              3.00    RUN
6 VISUAL RG?
              2.00    RUN
7 REL HUMID?
               .90    RUN
8 AIR TEMP?
             10.00    RUN
RAIN RATE?
              5.00    RUN
======
CHANGES?
                      RUN
ANALYSIS NO?
             24.00    RUN
RECOGNIZED
RANGE 1.88
======
CHANGES?
              6.00    RUN
6 VISUAL RG?
              3.00    RUN
RAIN RATE?
              5.00    RUN
======
CHANGES?
                      RUN
ANALYSIS NO?
             24.00    RUN
RECOGNIZED
RANGE 1.80
```

```
======
CHANGES?
              6.00    RUN
6 VISUAL RG?
              1.00    RUN
RAIN RATE?
              5.00    RUN
======
CHANGES?
                      RUN
ANALYSIS NO?
             24.00    RUN
RECOGNIZED
RANGE 1.14
======
CHANGES?
              6.00    RUN
6 VISUAL RG?
              0.50    RUN
RAIN RATE?
              5.00    RUN
======
CHANGES?
                      RUN
ANALYSIS NO?
             24.00    RUN
RECOGNIZED
RANGE 0.68
======
CHANGES?
ANALYSIS NO?
             97.00    RUN
RANGE?
              0.50    RUN
8-12 TRANS 0.03
 VIS TRANS 0.01
======
CHANGES?
              6.00    RUN
6 VISUAL RG?
              1.00    RUN
RAIN RATE?
              5.00    RUN
```

```
======
CHANGES?
                      RUN
ANALYSIS NO
             [illegible]  RUN
RANGE?
               .50    RUN
8-12 TRANS 0.[illegible]
 VIS TRANS 0.0[illegible]
======
CHANGES?
              6.00    RUN
6 VISUAL RG?
              3.00    RUN
RAIN RATE?
              5.00    RUN
======
CHANGES?
                      RUN
ANALYSIS NO
             97.00    RUN
RANGE?
               .50    RUN
8-12 TRANS 0.[illegible]
 VIS TRANS 0.34
======
CHANGES?
              6.00    RUN
6 VISUAL RG?
              2.00    RUN
RAIN RATE?
              5.00    RUN
======
CHANGES?
                      RUN
ANALYSIS NO
             97.00    RUN
RANGE?
               .50    RUN
8-12 TRANS 0.[illegible]
 VIS TRANS 0.50
```

APPENDIX -- TGT_ACQ PROGRAM LISTING

```
 01*LBL "TGT ACQ"
CF 01  CF 02  0
"PRINTER?"  PROMPT  X=Y?
SF 01  XEQ 09  XEQ 90
XEQ 91  XEQ 92  XEQ 93
GTO 10

 15*LBL 09
"1 SENSOR"  PROMPT
STO 03  GTO IND 03

 20*LBL 01
2.7  STO 24  3.51
STO 25  .97  STO 26  RTN

 28*LBL 02
6.9  STO 24  3.54
STO 25  2.883  STO 26
RTN

 36*LBL 03
5  STO 24  3.51  STO 25
.76  STO 26  RTN

 44*LBL 04
15  STO 24  3.51  STO 25
2.29  STO 26  RTN

 52*LBL 05
"HOPZ FOV?"

 54*LBL 10
PROMPT  STO 24
"a VALUE?"  PROMPT  LN
CHS  STO 25  "b VALUE?"
PROMPT  STO 26  RTN

 65*LBL 91
"3 TARGET NO.?"  PROMPT
STO 12  GTO IND 12

 71*LBL 06
2.03  STO 13  RTN

 75*LBL 02
3.27  STO 13  RTN

 79*LBL 03
1.31  STO 13  RTN

 83*LBL 04
3.06  STO 13  RTN

 87*LBL 05
1.15  STO 13  RTN

 91*LBL 06
2.27  STO 13  RTN

 95*LBL 07
.76  STO 13  RTN

 99*LBL 08
3.8  STO 13  RTN

103*LBL 09
2  STO 13  RTN

107*LBL 10
2.4  STO 13  RTN

111*LBL 11
.8  STO 13  RTN

115*LBL 12
116*LBL 14
2.27  STO 13  RTN

120*LBL 13
121*LBL 15
.87  STO 13  RTN

125*LBL 16
3.8  STO 13  RTN

130*LBL 17
1.74  STO 13  RTN

137*LBL "AT"
3.91E  STO 01  0  STO 05
STO 11  GTO IND 15

144*LBL 20
"MAIN RATE?"  PROMPT
STO 02  .0115  *  1  +
RCL 02  /  1/X  .1475  *
.1475  +  STO 05  STO 11
1.76  STO 02  1.22
STO 03  GTO 06

162*LBL 03
163*LBL 01
1.45  STO 02  6.31
STO 03

170*LBL 06
RCL 16  RCL 02  Y^X
RCL 03  *  1  +  RCL 16
*  RCL 01  /  1/X
RCL 05  +  STO 05

184*LBL 18
273.16  STO 00  RCL 17
+  STO 03  5193  /  1/X
CHS  E^X  8757 E4  *
RCL 17  *  STO 01
.0000456  *  RCL 03  *
STO 04  1  -  CHS  .002
*  STO 06  RCL 03  2^
/  1/X  1  -  6.08  *
E^X  RCL 04  *  RCL 00
+  STO 06  RCL 00
RCL 03  /  .4^  Y^X
RCL 01  *  STO 02
RCL 06  *  8.69  *
STO 06  RCL 02  SQRT
.06  *  STO 29  RCL 00
RCL 05  +  STO 28  RTN

240*LBL 19
SF 02  0  "
AVIEW  "CHANGES "
PROMPT  SF  *  STO 02
ENTER^  99  X=0?
GTO 38  XEQ IND 02
GTO 10

254*LBL 38
"ERROR"  AVIEW  BEEP

260*LBL 14
RCL 00  "ANGULAR ACC"
PROMPT  STO 00
XEQ IND 00  GTO 14

276*LBL 39
XEQ 01  XEQ 2  XEQ
XEQ 20  XEQ 03  XEQ 21
XEQ 04  XEQ 22  XEQ 25
XEQ 26  RTN

LBL 21
XEQ 01  XEQ 26  RTN

LBL 22
XEQ 02  XEQ 26  RTN

LBL 23
XEQ 03  XEQ 26  RTN

LBL 24
XEQ 04  XEQ 26  RTN

LBL 25
XEQ 05  XEQ 26  RTN

LBL 39
XEQ 29  XEQ 01  XEQ 29
XEQ 59  XEQ 02  XEQ 29
XEQ 59  XEQ 03  XEQ 29
XEQ 59  XEQ 04  XEQ 29
XEQ 59  XEQ 05  XEQ 29
XEQ 59  RTN
```

TGT_ACQ PROGRAM LISTING (CONT'D)

```
325•LBL 31
XEQ 79  XEQ 81  XEQ 39
XEQ 59  RTN

331•LBL 32
XEQ 79  XEQ 82  XEQ 39
XEQ 59  RTN

337•LBL 33
XEQ 79  XEQ 83  XEQ 39
XEQ 59  RTN

343•LBL 34
XEQ 79  XEQ 84  XEQ 39
XEQ 59  RTN

349•LBL 35
XEQ 79  XEQ 85  XEQ 39
XEQ 59  RTN

355•LBL 40
XEQ 47  XEQ 81  XEQ 41
XEQ 82  XEQ 43  XEQ 87
XEQ 48  XEQ 84  XEQ 48
XEQ 65  XEQ 46  RTN

368•LBL 41
XEQ 47  XEQ 81  XEQ 48
RTN

373•LBL 42
XEQ 47  XEQ 82  XEQ 48
RTN

378•LBL 43
XEQ 47  XEQ 83  XEQ 48
RTN

383•LBL 44
XEQ 47  XEQ 84  XEQ 46
RTN

388•LBL 45
XEQ 47  XEQ 85  XEQ 48
RTN

393•LBL 97
XEQ 79  RCL 20  RCL 23
*  STO 01  RCL 20  SQRT
RCL 29  *  RCL 01  +
CHS  E↑X  STO 01
"8-12 TRANS "  ARCL 01
AVIEW  3.912  RCL 16  /
RCL 11  +  RCL 20  *
CHS  E↑X  STO 02
" VIS TRANS "  ARCL 02
AVIEW  RTN

425•LBL 81
"DETECTED"  AVIEW  .25
STO 10  RTN

431•LBL 82
"CLUT DETECT"  AVIEW  1
STO 10  RTN

437•LBL 83
"CLASSIFIED"  AVIEW  2
STO 10  RTN

443•LBL 84
"RECOGNIZED"  AVIEW  4
STO 10  RTN

449•LBL 85
"IDENTIFIED"  AVIEW  8
STO 10  RTN

455•LBL 47
"SEARCH FOV?"  PROMPT
STO 23  "RANGE?"  PROMPT
STO 20  RTN

463•LBL 48
XEQ 39  XEQ 60
"WHAT PROB?"  PROMPT
STO 22  RCL 00  X<Y?
GTO 38  /  1  -  CHS  LN
CHS  3.4  *  RCL 23  *
RCL 24  /  RCL 03  /
STO 04  "TIME "  ARCL 04
AVIEW  ADV  FS? 01  STOP
RTN

494•LBL 79
"RANGE?"  PROMPT  STO 20
RTN

499•LBL 39
0  STO 03  RCL 20
RCL 28  *  STO 04
RCL 20  SQRT  RCL 29  *
RCL 04  +  STO 04
RCL 07  RCL 25  +
RCL 04  -  RCL 26  /
RCL 13  *  RCL 20  /
STO 03  XEQ 37  RTN

527•LBL 26
XEQ 29  XEQ 29  XEQ 29
XEQ 29  "RANGE "
ARCL 06  AVIEW  RTN

536•LBL 29
RCL 29  RCL 06  SQRT  /
RCL 28  +  STO 04
RCL 19  RCL 10  *
RCL 13  /  RCL 26  *
RCL 04  +  STO 04
RCL 07  RCL 25  +
RCL 04  /  STO 06  RTN

561•LBL 37
RCL 03  RCL 10  /
STO 03  .7  *  2.7  +
STO 04  RCL 03  RCL 04
Y↑X  STO 08  1  +
RCL 08  /  1/X  STO 08
RTN

[illegible]•LBL [illegible]
"PROBABILITY "  [illegible]
AVIEW  FS? 01  STOP  RTN

[illegible]•LBL [illegible]
"[illegible] "  [illegible]
AVIEW  FS? 01  STOP  RTN

[illegible]•LBL [illegible]
GTO 19  RTN

[illegible]•LBL [illegible]
"[illegible] DELTA T?"  PROMPT  LN
STO 07  RTN

[illegible]•LBL [illegible]
"4 [illegible]"  PROMPT
STO [illegible]  1  -  [illegible]
RCL 21  [illegible]
RCL 21  [illegible]
[illegible]  STO 04  RCL [illegible]
RCL 04  Y↑X  STO [illegible]  RTN

[illegible]•LBL [illegible]
"5 WEATHER?"  PROMPT
STO 15  FS? 0[illegible]  GTO [illegible]

[illegible]•LBL [illegible]
"6 VISUAL FOV?"  PROMPT
STO 16  FS? 0[illegible]  GTO [illegible]

[illegible]•LBL [illegible]
"7 REL HUMID?"  PROMPT
STO 17  FS? 0[illegible]  GTO [illegible]

[illegible]•LBL [illegible]
"8 AIR TEMP?"  PROMPT
STO 1[illegible]

[illegible]•LBL [illegible]
GTO "[illegible]"  .END.
```

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